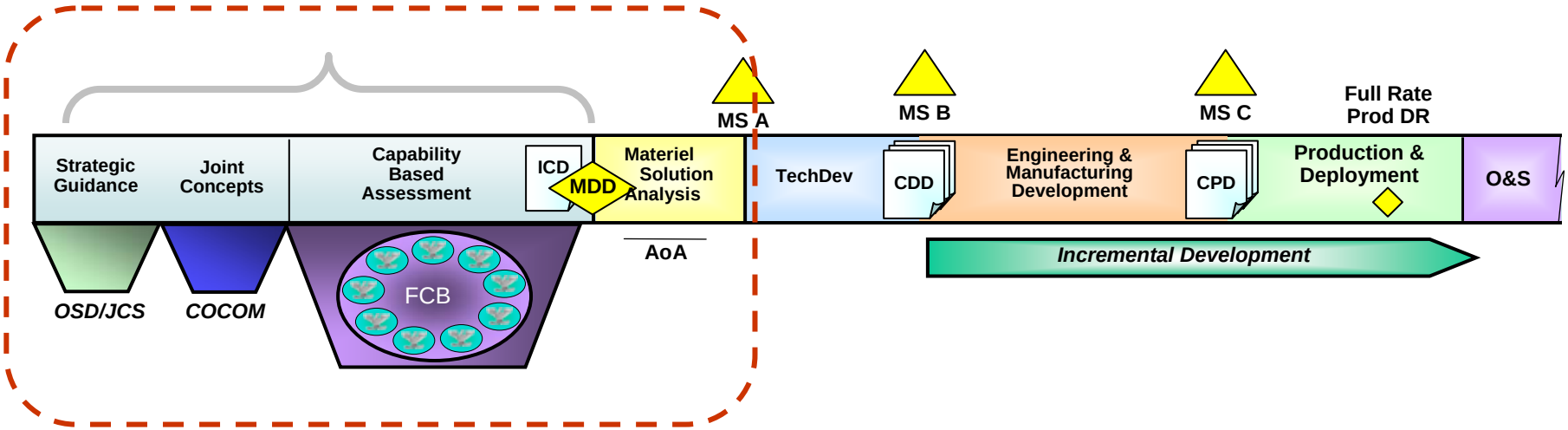
Pre-Milestone A

The Concept Design Realm



Steven Wynn

NAVSEA 05D1

What is Concept Design?

"A concept is a visualization of future operations that describes how a commander, using military art and science, might employ capabilities necessary to meet future challenges and explore potential opportunities."

– Naval Warfare Development Command

So...

Concept Design is the art of translating proposed operational capabilities into feasible acquisition options

Why Do We Perform Concept Studies?

- Requirements support
  - Analysis of Material Approaches for Initial Capabilities Document
  - Budget wedge justification
  - Cost tradeoffs during later design stages
- Force architecture assessments
- Technology impact assessments
- Analyses of Alternatives
- Independent check of outside ideas

Design Stages

Concept Definition

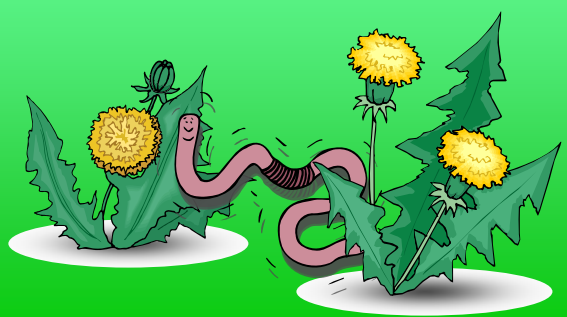
Rough Order of Magnitude (ROM) Design

Feasibility Design

Preliminary Design

Contract Design

Detailed Design



Concept Level Detail

- **Rough Order of Magnitude** - ROM level studies are used to reach broad conclusions quickly and economically. They rely on engineering judgment to make simplifying assumptions in lieu of time-consuming analysis. They identify major risk areas, but do not quantify them. ROM studies range in duration from a day to several months. A single naval architect or a small team generally conducts them. Interface with other technical warrant holders is typically limited.
- **Feasibility Studies** - Feasibility level studies use subject matter experts to analyze subsystems and total ship performance. Consequently, they provide a greater level of confidence than ROM studies in design accuracy and precision, but cost more and take more time. Technical risks are quantified in terms of probability and consequence of occurrence, and risk mitigation strategies are outlined. Feasibility studies for relatively simple designs may take a few months, while more complicated ones may take up to one year. Interface with other technical warrant holders is more extensive.

Design Stage Relative Levels of Effort

Concept Definition <10 People	ROM Design Synthesis <10 People	Feasibility Design Synthesis 10 – 100 People	Preliminary Design Synthesis 100 – 1000 People
Define Ship Concept	Synthesize ROM Design	Synthesize Feasibility Design	Synthesize Preliminary Design
Define operational concept	Evaluation - Estimate crew size	Define Feasibility Design margins	Define Preliminary Design margins
Define survivability concept	Evaluation - estimate required area and volume	Define hull and deckhouse geometry	Define hull and deckhouse geometry
Define ship-level capabilities	Define hull and deckhouse geometry	Define hull appendages	Define hull appendages
Define functions to achieve capabilities	Define hull appendages	Evaluation - Estimate crew size	Evaluation - Estimate crew size
Define function allocations to crew, hardware, software, or offboard	Define arrangements	Evaluation - estimate required area and volume	Evaluation - estimate required area and volume
Define mission systems	Define major stuctural elements	Define arrangements	Define arrangements
Define hull and deckhouse boundary conditions	Define propulsion system major components	Define major stuctural elements	Define major stuctural elements
Define subdivision relationships	Define electrical system major components	Define propulsion system major components	Define propulsion system major components
Define stuctural architecture	Define major command and surveillance systems	Define electrical system major components	Define electrical system major components
Define propulsion system architecture	Define major auxiliary systems	Define major command and surveillance systems	Define major command and surveillance systems
Define electrical system architecture	Define major outfitting systems	Define major auxiliary systems	Define major auxiliary systems
Define command and surveillance systems architecture	Define major combat system components	Define major outfitting systems	Define major outfitting systems
Define auxiliary systems architecture	Evaluation - Estimate mass properties	Define major combat system components	Define major combat system components
Define outfitting systems architecture	Evaluation - Calculate displacement	Evaluation - Estimate mass properties	Evaluation - Estimate mass properties
Define combat systems architecture (including aviation)	Evaluation - Compare weight to displacement	Evaluation - Calculate displacement	Evaluation - Calculate displacement
Define design margins	Evaluate structures	Evaluation - Compare weight to displacement	Evaluation - Compare weight to displacement
	Evaluate adequacy of available area and volume versus requirement	Evaluate structures	Evaluate structures
	Evaluation - Compare required to available area/volume	Evaluation - Calculate available area and volume	Evaluation - Calculate available area and volume
	Evaluation - Evaluate intact and damaged stability	Evaluation - Compare required to available area/volume	Evaluation - Compare required to available area/volume
	Evaluate propulsion system performance	Evaluation - Evaluate intact and damaged stability	Evaluation - Evaluate intact and damaged stability
	Evaluate electrical system performance	Evaluate propulsion system performance	Evaluate propulsion system performance
	Evaluation - Compare estimated manpower requirements with crew size	Evaluate electrical system performance	Evaluate electrical system performance
	Evaluation - Estimate costs	Evaluation - compare estimated manpower requirements with crew size	Evaluation - compare estimated manpower requirements with crew size
	Evaluate Suceptibility	Evaluation - Estimate costs	Evaluation - Estimate costs
	Evaluate Vulnerability	Evaluate Suceptibility	Evaluate Suceptibility
	Evaluate Recoverability	Evaluate Vulnerability	Evaluate Vulnerability
	Evaluate operational effectiveness	Evaluate Recoverability	Evaluate Recoverability
	Evaluate need to re-define concept based on evaluated performance versus requirements	Evaluate operational effectiveness	Evaluate operational effectiveness
	Evaluate need to re-synthesize ROM design based on evaluated performance versus requirements	Same as Synthesize ROM Design, plus...	Define data exchange requirements
		Define data exchange requirements	Evaluate internal arrangements performance
		Evaluate internal arrangements performance	Evaluate topside arrangements performance
		Evaluate topside arrangements performance	Evaluate motions and seaway loads
		Evaluate motions and seaway loads	Evaluate maneuverability
		Evaluate maneuverability	Evaluate HVAC systems performance
		Evaluate HVAC systems performance	Evaluate cargo and ammunition handling systems
		Evaluate cargo and ammunition handling systems	Evaluate combat system performance
		Evaluate combat system performance	Evaluate total ship mission performance
		Evaluate total ship mission performance	Same as Synthesize Feasibility Design, plus...
		Evaluate need to re-define concept based on evaluated performance versus requirements	
		Evaluate need to re-synthesize ROM design based on evaluated performance versus requirements	Evaluate/Estimate RMA --- B7
		Evaluate need to re-synthesize Feasibility Design based on evaluated performance versus requirements	Evaluate/Estimate Access & Pers Flow --- C2
			Evaluate/Estimate/Develop Area/Volume Report --- C2
			Evaluate/Estimate Navigation Limits --- C2
			Evaluate/Estimate/Develop Weight Report --- C3
			Evaluate/Estimate Resistance & Powering --- C4
			Evaluate/Estimate Hydrodynamic Performance --- C4
			Evaluate/Estimate Habitability & Crew Services --- C7
			Evaluate/Estimate Environmental System Performance --- D6
			Evaluate/Estimate Aux (18) Systems Performance --- D7
			Evaluate/Estimate Machinery Control System --- D9
			Evaluate/Estimate Steering & Motion Control Systems --- D10
			Evaluate/Estimate Combat Systems Performance --- E2
			Evaluate/Estimate Electro-Magnetic Compatibility --- E4
			Evaluate/Estimate RadHaz --- E5
			Evaluate/Estimate Weapon Systems Coverage, Blast Zones, etc --- E6
			Evaluate/Estimate C4ISR Systems Performance --- F5
			Evaluate/Estimate LAN Systems Adequacy --- F8
			Evaluate/Estimate Hab & Crew Service Adequacy & Performance --- H1
			Evaluate/Estimate Crew Requirement Based on Installed Systems --- H4
			Evaluate/Estimate Stores & Ammunition Handling Systems & Flow --- M2
			Evaluate/Estimate Anchoring, Mooring, & Towing Systems --- M5
			Evaluate/Estimate Boat, UMV & Towed Body Systems --- M6
			Evaluate/Estimate CBR Protection --- S13
			Evaluate/Estimate Flight Deck & Hangar Design --- V2
			Evaluate/Estimate Aircraft Maintenance Facilities --- V3
			Evaluate/Estimate Aircraft Flight Environment --- V4
			Evaluate/Estimate Aircraft Landing & Comm Aids --- V5
			Evaluate need to re-define concept based on evaluated performance versus requirements
			Evaluate need to re-synthesize ROM Design based on evaluated performance versus requirements
			Evaluate need to re-synthesize Feasibility Design based on evaluated performance versus requirements
			Evaluate need to re-synthesize Preliminary Design based on evaluated performance versus requirements

Concurrent Design

Concept Definition

Activities

- Define operational concept
- Define survivability concept
- Define ship-level capabilities
- Define functions to achieve capabilities
- Define function allocations to crew, hardware, software, or offboard
- Define mission systems
- Define hull and deckhouse boundary conditions
- Define subdivision relationships
- Define structural architecture
- Define propulsion system architecture
- Define electrical system architecture
- Define command and surveillance systems architecture
- Define auxiliary systems architecture
- Define outfitting systems architecture
- Define combat systems architecture (including aviation)
- Define design margins

Tools

- Defense Guidance
- Joint Functional, Integrating, and Operating Concepts
- Design Guidance (i.e., Survivability Handbook, Naval Vessel Rules, etc.)
- Historical information libraries
- Advanced Surface and Submarine Evaluation Tool (ASSET) wizards
- Early Stage Manpower Assessment Tool (Coming soon)

Fundamental system architecture decisions made early on can drive program costs!

ROM Design Synthesis

Activities

- Evaluation - Estimate crew size
- Evaluation - estimate required area and volume
- Define hull and deckhouse geometry
- Define hull appendages
- Define arrangements
- Define major structural elements
- Define propulsion system major components
- Define electrical system major components
- Define major command and surveillance systems
- Define major auxiliary systems
- Define major outfitting systems
- Define major combat system components
- Evaluation - Estimate mass properties
- Evaluation - Calculate displacement
- Evaluation - Compare weight to displacement
- Evaluate structures

Activities (continued)

- Evaluate adequacy of available area and volume versus requirement
- Evaluation - Compare required to available area/volume
- Evaluation - Evaluate intact and damaged stability
- Evaluate propulsion system performance
- Evaluate electrical system performance
- Evaluation - compare estimated manpower requirements with crew size
- Evaluation - Estimate costs
- Evaluate Susceptibility
- Evaluate Vulnerability
- Evaluate Recoverability
- Evaluate operational effectiveness
- Evaluate need to re-define concept based on evaluated performance versus requirements
- Evaluate need to re-synthesize ROM design based on evaluated performance versus requirements

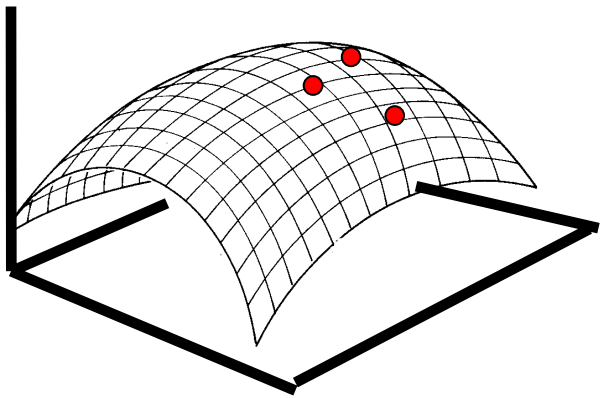
Main tools are ASSET, cost tools, and experience

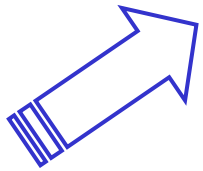
ROM Design Synthesis (cont.)

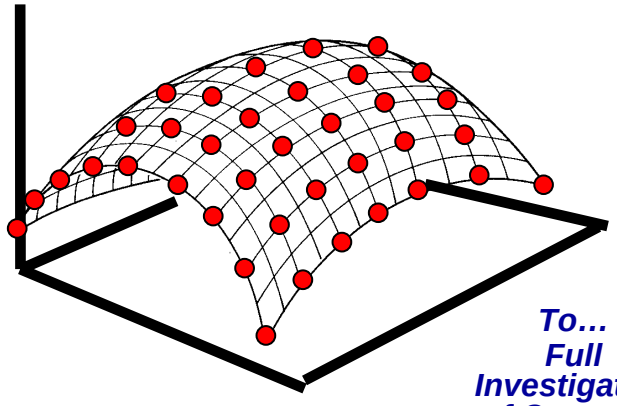
- Many activities create feedback loops
- Rapid iteration possible only because of automated “balancing” tools like ASSET
- Iteration speed falls off dramatically as design team expands

Design Space Exploration

From…
Limited Investigation of relatively few Design Points







To…
Full Investigation of Concepts throughout the Design Space

- Requires fully automated design synthesis capability
- Goal is multivariate optimization
- Knowledge of tool validation boundaries is critical
- Currently limited to very rough order assessments

Feasibility Design Synthesis

- Number of design activities depends on ship functionality (Surface combatant > Sealift)
- ASSET useful for integrating many analysis results, but study pace slows to a crawl when exceptions are on the critical path
- NAVSEA is starting to adopt methods such as set-based design to manage risks from incomplete analyses
- ROM design excursions common during feasibility design studies

Concept Design Products

- Capability description
- Statement of assumed operational concept
- Description of potential material solutions
- Cost estimate
- Risk assessment
  - Risks associated with the concept
    - Integration Complexity
    - Technology Development
    - Requirements Maturity
  - Risks associated with the study
    - Design Detail
    - Design Process
    - Analysis Process

Questions?